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Wireless Relay Communication with Coding

Salim Kahveci

***Abstract*—Wireless communications performance is badly affected by channel fading issue. Some diversity techniques are used to reduce the impact of fading by conveying data over multiple independent fading channel paths and combine them at the receiver side. Cooperative diversity is a novel communication technique where multiple terminals use their resources in cooperative manner to form a virtual array that realizes spatial diversity gain in a distributed fashion. Cooperative relay system can obtain reliable communications, capacity gain and energy saving by mutual relaying among users of wireless network.**

***Keywords—cooperative communication*, coding, error probability**

I. Introduction

A simplified model of classical communication system [1] is shown in Figure 1.

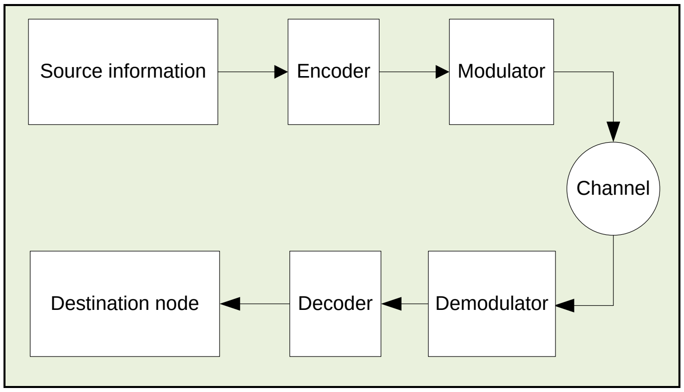

Figure 1. A simplified model of communication system

It consists of transmitter block, transmission channel and receiver block. Transmitter block includes source node to transmit packet symbols of the original message in binary form, encoder to encode the received packets and forwards them, and modulator to modulate the coded packet symbols. Transmission channel represents the media, between sender and receiver, through which the message will be transmitted. Receiver block includes demodulator to demodulate the incoming packets and sends them to decoder, decoder to decode the received packets and forward them to their final destination node, and destination node the final point where message should be delivered.

Salim Kahveci / Department of Electrical&Electronics Engineering
Karadeniz Technical University, 61080
Trabzon-TURKEY

II. Repetition Coding

One of the simplest block codes [2] is the simple repetition code in which the added redundant bits are just a repetition of the original bits. Repetition code is a coding scheme that repeats the bits across the channel to achieve an error free communication.

In repetition code the encoder is just repeats the received bit symbol that transmitted from source and forwards it. The decoder compares the received symbol to a list of code words, and chooses the correct word based on the minimum distance technique. The use of repetition code can add diversity to the system since two copies of the message will be sent through they use the same channel.

Error probability is used to measure the performance of a communication system. Symbol error probability is the probability that a symbol transmitted by source node will be received erroneously. For better performance measure errors also could be count at bit level and find the bit error probability, often referred to as bit error rate (BER). The error probability for binary antipodal signal transmitted through a Rayleigh fading channel [3, 4] with perfect channel state information (CSI) is given by

$$BER = p(e) = \frac{1}{2}\left[1 - \sqrt{\frac{S/N_o}{1 + S/N_o}}\right] \quad (1)$$

Where S is the average received energy and N_0 is power spectrum density of the White Gaussian Additive Noise (AWGN) [4].

III. Cooperative Relay System

Figure 2 illustrates cooperative communication relay system where it has source node (**S**), destination node (**D**), and a neighboring node working as a relay (**R**) to the source signal.

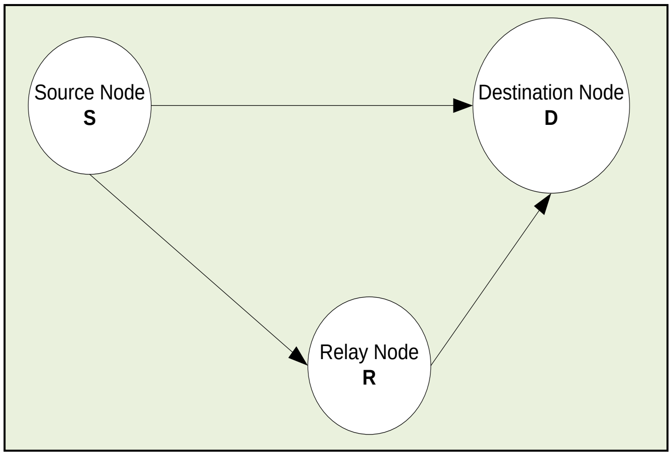

Figure 2. The cooperative relay communication model.

The source node transmits to destination node through direct path and in-direct (relay) path. Packets transmission occurred on two time slots. The source node transmits to both, destination and relay nodes, at the first time slot. At the second time slot, only the relay node transmits towards destination node.

If $\mathbf{m}$ represents the k transmitted bits, then the output of the encoder $\mathbf{c}$ is given by

$$\mathbf{c} = \mathbf{m}.G \tag{2}$$

Where G represents the code generator matrix. For simple repetition code of n bits, G is given by

$$G = \begin{bmatrix} 1_{11} & . & . & . & 0 & 1_{1n-k} & . & . & . & 0 \\ . & . & & & . & . & . & & & . \\ . & & . & & . & . & & . & & . \\ . & & & . & . & . & & & . & . \\ 0 & . & . & . & 1_{kk} & 0 & . & . & . & 1_{kn} \end{bmatrix} \tag{3}$$

Nothing that for repetition code $n = 2k$. The transmitted signal will be received at two phases [2, 5],

Time-Slot 1: At the first time slot the encoded transmitted message $\mathbf{c}$ will be received by relay and destination. The received signal at destination and relay respectively are given by

$$\begin{aligned} y_{sd} &= a_{sd}\sqrt{E}c_1 + n_d \\ y_{sr} &= a_{sr}\sqrt{E}c_1 + n_r \end{aligned} \tag{4}$$

Time-Slot 2: In this time slot, only the relay transmits to the destination. Hence the received signal is

$$y_{rd} = a_{rd}\sqrt{E}c_2 + n_d \tag{5}$$

In (4) and (5), E is the mean received energy, a is the complex non-selective Gaussian fading coefficient, $\mathbf{c}$ is the received signal and n is complex AWGN with power spectrum density N_0. In order to find the original transmitted symbol, the receiver combines both signals, the signal received from source and the signal received from relay to get

$$y = [y_{sd}\; y_{rd}] \tag{6}$$

In this work, the transmission channel is assumed to be a flat (non-selective) fading channel in which all frequency components are affected by the same fading coefficients. The channel state information assumed to be known to the receiver.

The source transmits binary symbols. Coding technique is used in order to reduce errors of received signal and minimize the effect of noise and fading. The transmitted bits will be encoded before being transmitted and then decoded at the receiver. The encoder is using simple repetition code to encode the source output. The decode is using minimum Hamming distance to detect the transmitted signal. The noise at receiver is assumed to be White Additive Noise with Gaussian distribution of zero mean and variance $N_0/2$. Also binary modulation technique is used to modulate the code words.

IV. Simulation Results

We have simulated the system shown in Figure 2, which is consists of source to transmit packet symbols, relay work or cooperative mode to receive the symbols that sent by transmitter, in the first time slot, and then retransmit them towards destination, in the second time slot. The third part in this system is the destination which receives the packet symbols that sent by source and relay respectively. In order to assess the benefits that cooperative communications, we first measured the performance of non-cooperative systems that use repetition coding method.

The non-cooperative system simulated in two cases, constant fading and independent fading. Hence we have three different cases of communication methods. Non-cooperative repetition code with constant fading, non-cooperative repetition code with independent fading and cooperative with repetition code. In each of the three cases we count the probability of error as a function of signal to noise ratio (SNR).

During each transmission period and upon receiving the transmitted packets from source and relay, the destination combines the two received symbols, and then decodes the combined symbol by comparing it to a list of code words and finds the distance between the received word and each codeword. The decoder decides the correct word by choosing the codeword with the minimum distance to the received word.

We plotted the results, probability of error versus SNR, for all the simulated cases as well as the theoretical case of probability of error for fading channel. Figure 3 shows the graph of the non-cooperative communication system results. The graph illustrates the probability of errors of fading channel in three cases. These cases are theoretical, constant fading and independent fading. The results show that both of non-cooperative repetition code transmission have low probability of error compared to the theoretical case, hence transmission performance is improved by using the repetition code. The performance of the system is better in the independent fading case than the constant fading case, which supports the idea of cooperative communication.

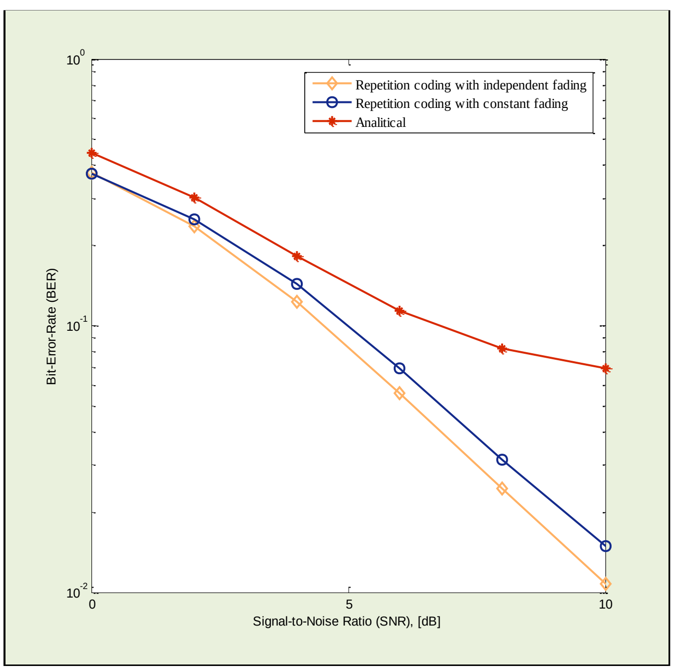

Figure 3. Error probability for simple repetition code.

Figure 4 shows the plotted results for cooperative communication system compared to the theoretical and non-cooperative system. From the graph we can easily notice that cooperative has low probability of error compared to the other methods.

The results showed that decode and forward cooperative transmission has better performance over non-cooperative with repetition code case and this could be justified since cooperative technique make use of both coding and cooperative specifications and benefits. The performance of the cooperative system increases with the increase of the codeword.

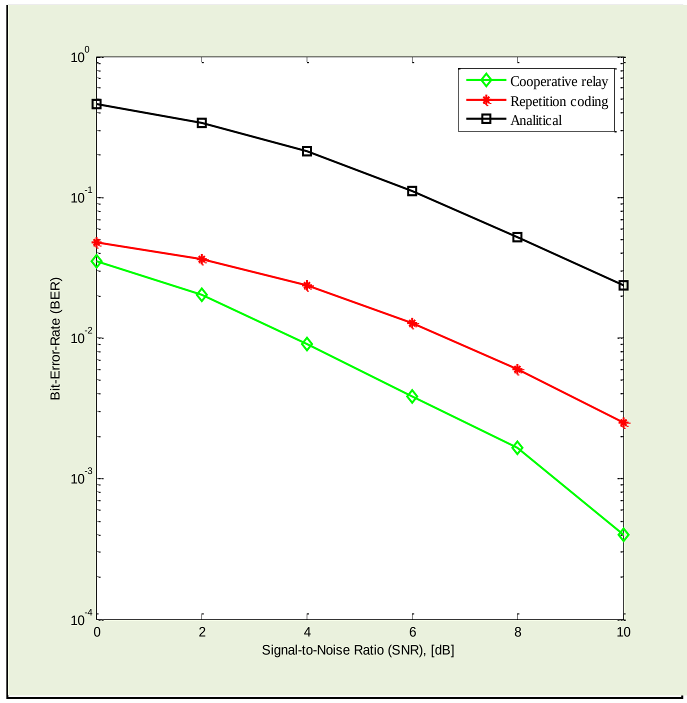

Figure 4. Error probability for cooperative system with repetition code.

V. Conclusions

In this work we considered the design of coded cooperative communication system and examined its BER-SNR performance. We showed that the repetition based relay channel can be used for cooperation and can achieve good performance for the communication networks. We conclude by nothing that the idea of mapping cooperative protocol onto simple relay channel can be extended to large networks and more complex transmission scheme.

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About Author (s):

Salim Kahveci was born in Trabzon, TURKEY. He received the B.Sc., M.Sc., and Ph.D. degrees in Electrical&Electronics Engineering from the Karadeniz Technical University, Tabzon, TURKEY, in 1996, 1999, and 2006, respectively. From September 2010 to June 2011, he has been a Postdoctoral Researcher, with the Signal Processing Laboratory, Department of Electrical Engineering, Columbia University, New York, USA. He is now an Assoc. Prof. at Karadeniz Technical University. His field of interest research includes wireless communications, signal processing, information theory and channel codes.